SULFUR HISTORY AND FUTURE

Lessons from the 132 years of Sanborn Field

Gurbir Singh, Rajinder Kaur, Harpreet Kaur, Kelly A. Nelson, Gurpreet Kaur, Rasel Parvej & Tim Reinbott

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Where is the Sanborn Field?

Established in **1888**, Sanborn Field at the University of Missouri is a long-term agricultural research site with more than 130 years of continuous management. The supplied dataset contains 0-48-inch soil depth **Mehlich-3 extractable sulfur** observations from 12 cropping and fertility treatments measured in 1888, 1915, 1938, 1962, 1988 and 2020.

Why does sulfur matter?

Sulfur is essential for **protein and amino-acid synthesis, chlorophyll formation, enzyme activity, crop quality and yield**. Because sulfur deficiency can resemble nitrogen deficiency, current soil and plant testing is important for diagnosis and nutrient-management decisions.

WHAT THE SANBORN FIELD DATA TELL US

Mehlich-3 extractable sulfur by treatment and year for 0-48-inch soil profile

Treatments	1888	1915	1938	1962	1988	2020
CW No-fertility	¶807 a D	353 a B	1178 c E	915 h D	564 e C	240 ef A
CW Manure + N	807 a D	476 bcde C	845 b D	484 bcde C	286 abc B	69 b A
CW Manure	807 a E	388 ab C	770 b E	596 ef D	257 a B	139 c A
CW Full fertility	807 a D	517 cde C	1457 c E	787 gh D	250 ab B	50 a A
CT No-fertility	807 a E	600 cdef D	385 a C	288 a A	369 cd BC	298 fg AB
CT Manure	807 a E	580 de D	736 b E	488 cd C	316 bc B	255 f A
CC No-fertility	807 a C	480 cd B	760 b C	758 gh C	453 d B	186 d A
CC Manure	807 a D	614 ef C	842 b D	614 defg C	401 d B	202 de A
CWRC No-fertility	807 a E	488 c C	709 b D	476 c C	310 bc B	209 de A
CWRC Manure + N	807 a D	579 de A	682 b BC	670 fg BC	739 f CD	608 h AB
CWRC Full fertility (-N)	807 a D	705 f D	749 b D	390 b C	285 ab B	145 c A
CWRC Full fertility	807 a C	572 cdef B	756 b BC	708 gh BC	744 f BC	368 g A

S (lbs ac[-1]) color scale: 0, 200, 400, 600, 800, 1000, 1200, 1400, 1600

CW – Continuous Wheat CT – Continuous Timothy CC – Continuous Corn CWRC – Corn-Wheat-Red Clover

¶Small letters shows significant difference among treatments and capital letters show significant differences between years for a particular treatment ($p<0.05$).

Mean Mehlich-3 extractable sulfur across all 12 treatments

Year	1888	1915	1938	1962	1988	2020
Mean S (lbs ac^{-1})	807	529	822	598	415	232

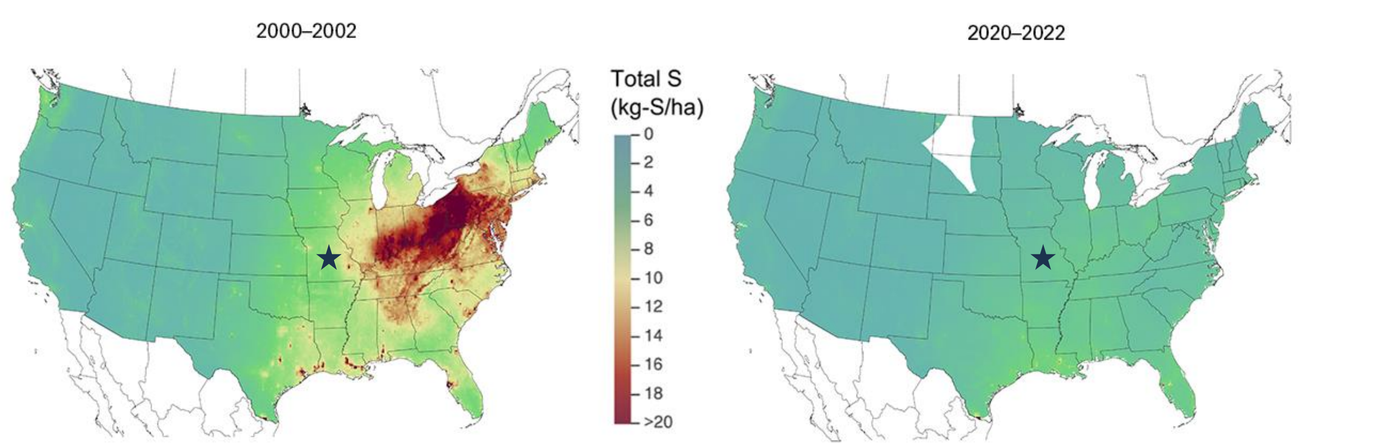
Key observations

- All treatments started at **807 lbs S ac^{-1}** in 1888 (based on Tucker Prairie soil samples).
- The mean reached **822 lbs S ac^{-1}** in 1938, then declined to **598** in 1962, **415** in 1988
- and **231** in 2020.
- The long-term record shows substantial divergence among cropping and fertility systems.

What may be driving the decline?

The supplied material identifies **reduced atmospheric sulfur deposition after clean-air regulations, sulfate leaching**, **crop sulfur removal**, and modern high-analysis fertilizers with little or no sulfur as important factors.

Bottom line: sulfur supply has changed substantially over time, and the Sanborn record shows that **cropping system and fertility management strongly influence extractable sulfur remaining in the soil profile.**



Source: CASTNET/CMAQ/NADP
USEPA, 2024

Image shows atmospheric sulfur deposition in the continental US from 2000-2002 and 2020-2022 and star indicates location of the Sanborn Field in Missouri

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TREATMENT MATTERS: NOT ALL SYSTEMS ARE EQUAL

Treatment	1888	1938	2020	2020 / 1888
CW No-fertility	807	1178	240	30%
CW Manure + N	807	845	69	9%
CW Manure	807	770	139	17%
CW Full fertility	807	1457	50	6%
CT No-fertility	807	385	298	37%
CT Manure	807	736	255	32%
CC No-fertility	807	760	186	23%
CC Manure	807	842	202	25%
CWRC No-fertility	807	709	209	26%
CWRC Manure + N	807	682	608	75%
CWRC Full fertility (-N)	807	749	145	18%
CWRC Full fertility	807	756	368	46%

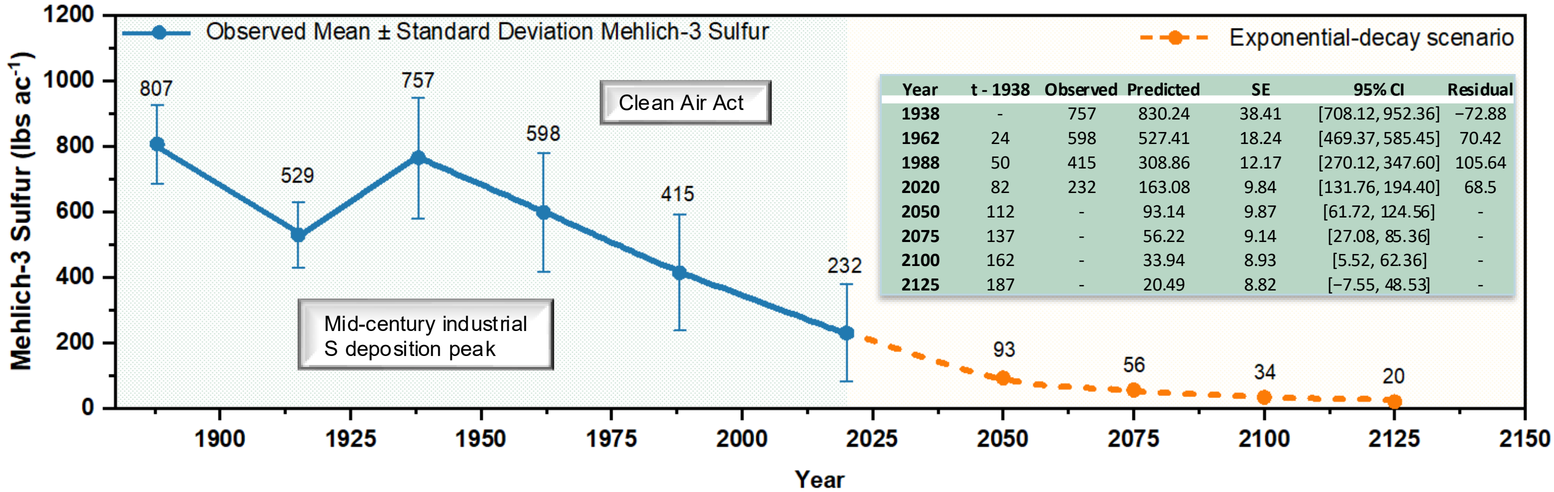
CW = continuous wheat; CT = continuous timothy; CC = continuous corn; CWRC = corn–wheat–red clover rotation.

Highest 2020 sulfur:
CWRC Manure + N = **608 lbs S ac^{-1}** — about 75% of its 1888 value.

Lowest 2020 sulfur:
CW Full Fertility = **50 lbs S ac^{-1}**; CW Manure + N = **69 lbs S ac^{-1}**.

PREDICTING THE NEXT 100 YEARS

Sanborn Field sulfur trajectory: observed values and 2020-2125 scenario



Year	t - 1938	Observed	Predicted	SE	95% CI	Residual
1938	-	757	830.24	38.41	[708.12, 952.36]	−72.88
1962	24	598	527.41	18.24	[469.37, 585.45]	70.42
1988	50	415	308.86	12.17	[270.12, 347.60]	105.64
2020	82	232	163.08	9.84	[131.76, 194.40]	68.5
2050	112	-	93.14	9.87	[61.72, 124.56]	-
2075	137	-	56.22	9.14	[27.08, 85.36]	-
2100	162	-	33.94	8.93	[5.52, 62.36]	-
2125	187	-	20.49	8.82	[−7.55, 48.53]	-

EXPONENTIAL-DECAY SCENARIO	**Model:** $S(t) = 830.24 \pm 38.41 \times e^{-0.019874 \pm 0.001203\,(t-1938)}$ Fitted to the **1938–2020 mean trends with S half life of 34.88 yrs**. This is a scenario for continued decline, not a guaranteed future soil-test result. For 1938 outliers were removed.
Projected mean S (lbs ac^{-1})	**2050:** 93 | **2075:** 56 | **2100:** 34 | **2125:** 20

WHAT CAN GROWERS AND DECISION MAKERS DO?

Practical sulfur management

- **Soil and plant tissue testing** using current recommendations.
- Account for **crop sulfur removal**, especially in high-yield systems.
- Consider sulfur sources such as **ammonium sulfate, gypsum, elemental sulfur, manure or sulfur-containing blends** when appropriate.
- Pay attention to **continuous cropping systems** where the Sanborn Field record shows stronger depletion.
- Use precision application technology to apply sulfur where needed so negative effects of sulfur application don't hinder crop production.

Soil-testing guidance

Mehlich-3 extraction for Missouri soils and periodic monitoring in high-removal systems for soil nutrient levels is recommended. Note that sulfur can be immobilized in organic matter and sulfates can move below the surface soil profile therefore sulfur fertilizer management should target grain or crop removals.

Important: Sanborn Field values are long-term experimental observations and should not be used as universal sufficiency thresholds for individual fields. Use current University of Missouri recommendations and field-specific soil tests for management decisions.

"As atmospheric sulfur inputs declined, sulfur management became increasingly intentional."

Data source: Mehlich-3 extractable sulfur from the Sanborn Field experiment, Columbia, Missouri (1888–2020), based on the supplied figure/data. **Projection note:** the 2020–2125 curve is an exponential-decay scenario fitted to the 1938–2020 mean trend. Actual sulfur availability will depend on weather, crop removal, atmospheric deposition, soil properties and management.

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